



space radiation analysis group

Lyndon B. Johnson Space Center



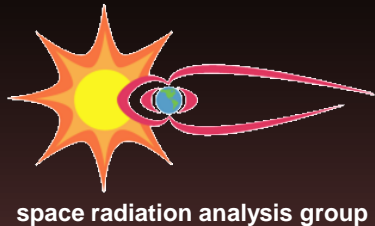
NCRP Review
Trapped and SPE Radiation Transport

Mark Weyland (LM/C23 -- X36193)

ESSSED / Space Radiation Analysis Group

Trapped and SPE Radiation Transport

Mark Weyland
Project Manager – Lockheed Martin



NCRP Review
Trapped and SPE Radiation Transport

Lyndon B. Johnson Space Center



Mark Weyland (LM/C23 -- X36193)

ESSSED / Space Radiation Analysis Group

Introduction

- During preflight assessments and real time operations, SRAG calculates crew exposures using different models and codes.
- The transport of protons and electrons is important for the estimation of exposure from the trapped radiation belts as well as from SPEs
- The GCR component is calculated using a semi-empirical model

Proton Transport

- The primary proton transport code used by SRAG:
 - » Name - PDOSE
 - » Utilizes the Continuous Slowing Down Approximation (CSDA)
 - » Ignores nuclear interactions
 - » All additional detector material is converted to an equivalent radiation thickness of the shielding material
 - » Dose integrated over proton spectrum 0-1000 MeV
 - » Stopping powers from Janni's range-energy tables for protons
 - » Quality factors for dose equivalent calculations from ICRP 26
 - » Integration performed by the Gaussian method – 9 points

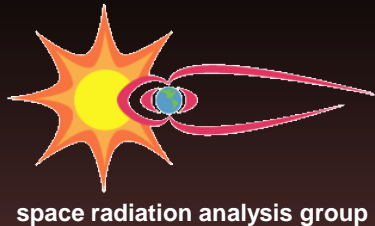
Proton Transport Cont.

» Input

- Proton spectrum
- Shield distribution files
- Shield and detector material
- Amount of additional detector material

» Output

- Total dose and dose equivalent
- Average quality factor behind the shield distribution
- A dose/dose equivalent vs. thickness table
- Resulting transmitted flux



NCRP Review
Trapped and SPE Radiation Transport

Mark Weyland (LM/C23 -- X36193)

ESSSED / Space Radiation Analysis Group

Solar Particle Event – Real Time (SPE-RT)

- SRAG has moral and legal responsibility of predicting astronaut exposures and ensuring doses remain ALARA
- No on-board telemetered radiation data coming from the Space Shuttle, and no real time telemetered data from ISS until flight 6A
- During the last solar maximum, 6 different codes had to be run to go from solar particle fluxes measured on NOAA GOES satellites, to actual dose numbers inside the Space Shuttle
- This “old” method was slow, poorly documented, and due to many assumptions was inaccurate
- STS-28 is the only Space Shuttle flight to date to receive solar particles – this happened at the end of the flight when the August 1989 SPE occurred

Solar Particle Event – Real Time (SPE-RT) cont.

- The old method over predicted the additional crew dose from this event by more than a factor of 1000
- SPE-RT corrects for many of the old method deficiencies
- Goal for SPE-RT – crew dose projections within 15% of measurements and be automated to run in near real time
- General description of SPE-RT:
 - » Determine vehicle location (trajectory file or state vectors)
 - » Calculate geomagnetic cutoff energy for protons (E_c) at vehicle location
 - » If $E_c > 3$ GeV, assume additional dose is zero and move to next vehicle location
 - » Obtain corresponding integral GOES proton flux $J(E) > 30$ MeV, and $J(E) > 100$ MeV
 - » Convert integral flux to differential flux
 - » Reduce “free-space” SPE spectrum to account for Earth shadowing at low Earth orbit
 - » Attenuate SPE spectra through vehicle shield distribution
 - » Calculate dose from attenuated SPE spectra
 - » Repeat procedure and integrate over desired trajectory period every 60 sec.

Solar Particle Event – Real Time (SPE-RT) cont.

- SPE-RT assumptions: geomagnetically quiet conditions, alpha and heavier particles are ignored, secondary particles are ignored
- SPE-RT has recently been upgraded to a fully automated tool. The existing Space Weather Alarm Code (SWAC) detects an increase in solar particles at GOES and starts SPE-RT automatically.
- Unfinished work:
 - » GUI interface for entering the initialization parameters
 - » Graphical display for the output

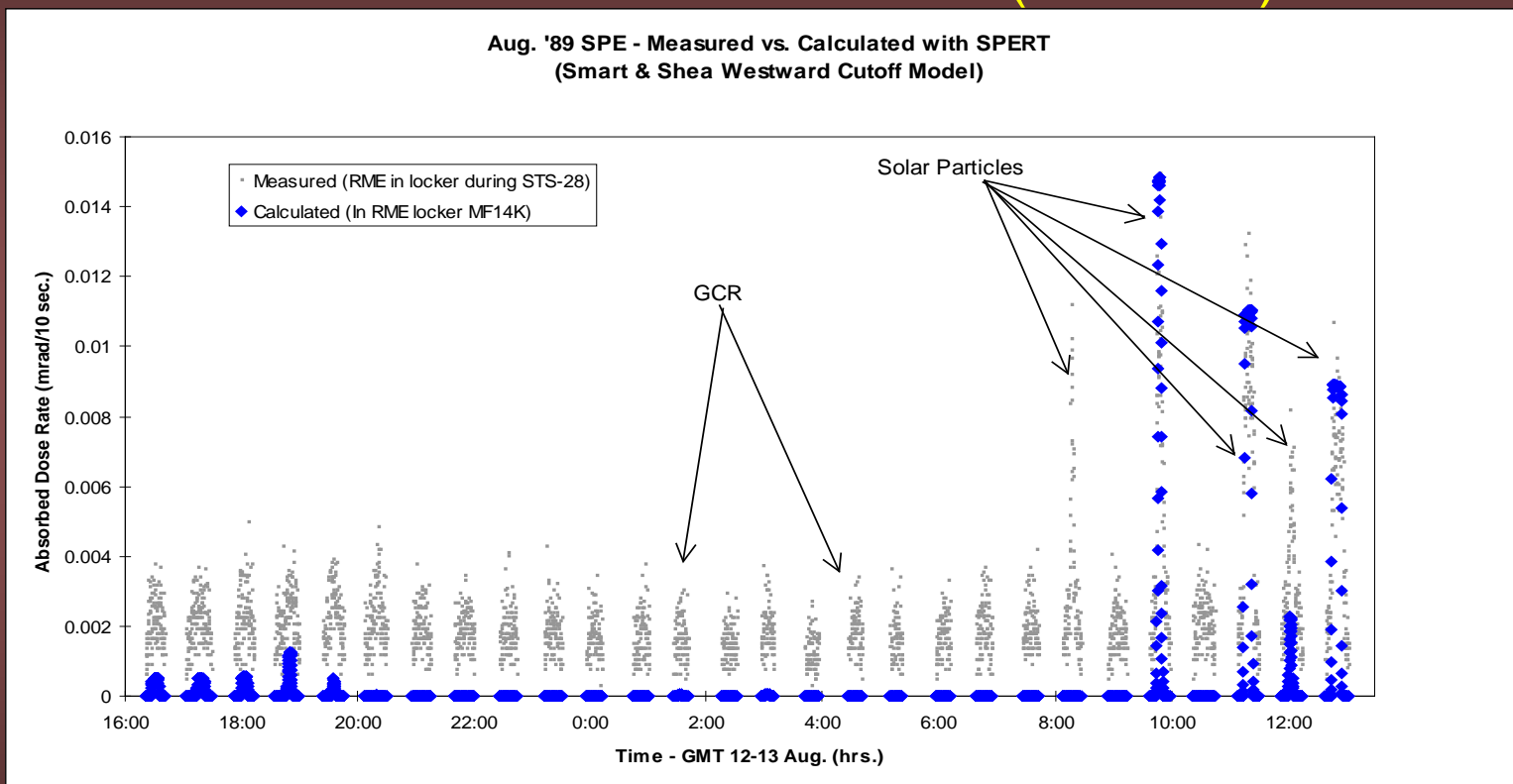


NCRP Review Trapped and SPE Radiation Transport

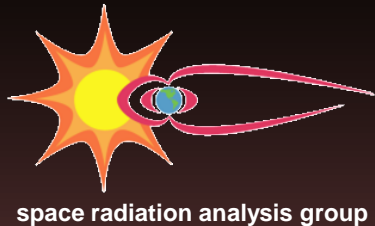
Mark Weyland (LM/C23 -- X36193)

ESSSED / Space Radiation Analysis Group

Solar Particle Event – Real Time (SPE-RT) cont.



- First test using measured data in LEO
- Missed one pass where RME measured solar protons (~8:30)
- Both over and under estimated dose during various passes



NCRP Review
Trapped and SPE Radiation Transport

Lyndon B. Johnson Space Center



Mark Weyland (LM/C23 -- X36193)

ESSSED / Space Radiation Analysis Group

Solar Particle Event – Real Time (SPE-RT) cont.

- Cumulative measured vs. SPE-RT inside the locker was within 3%
- SPE-RT over estimated the dose at a more lightly shielded location by a factor of 2



space radiation analysis group

Lyndon B. Johnson Space Center

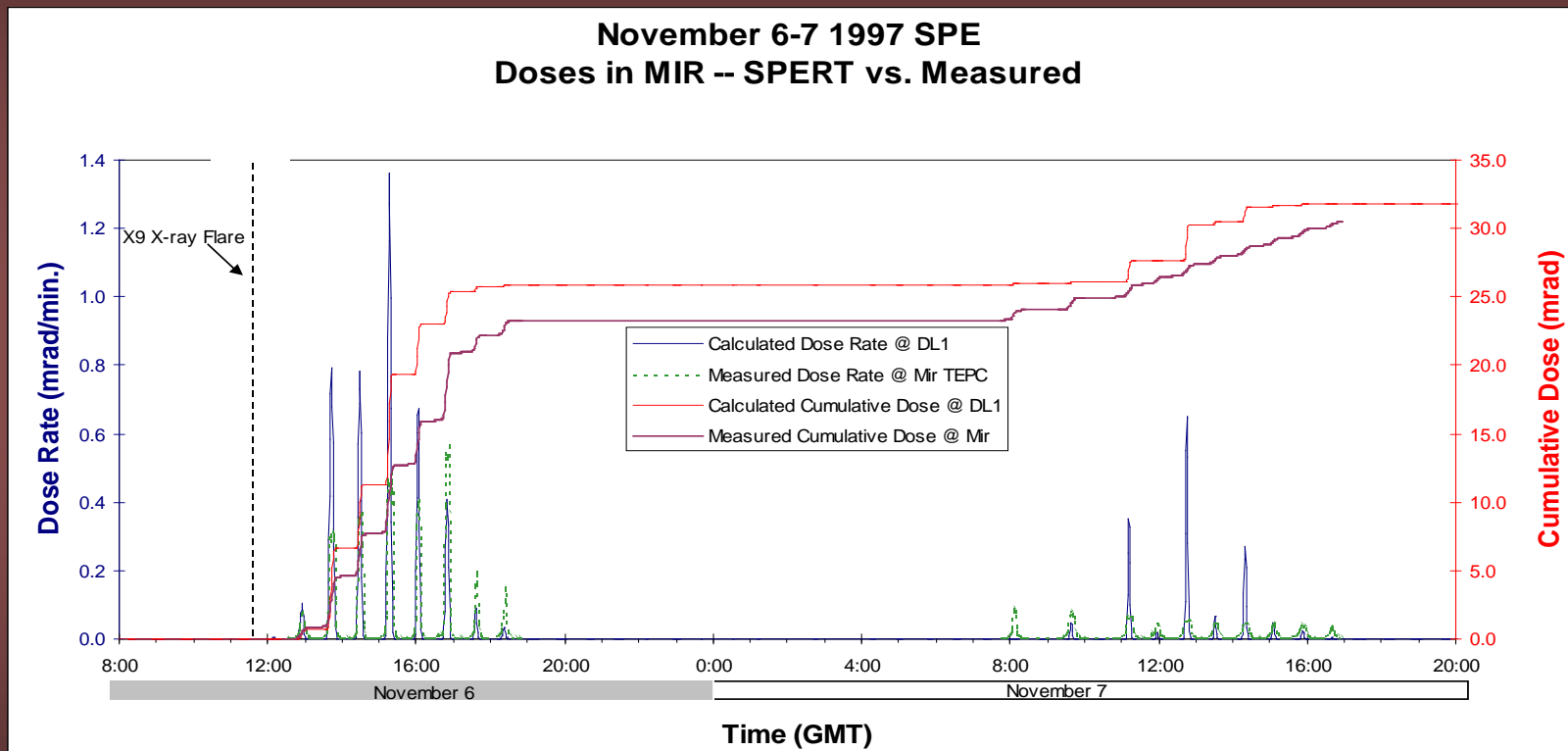


NCRP Review Trapped and SPE Radiation Transport

Mark Weyland (LM/C23 -- X36193)

ESSSED / Space Radiation Analysis Group

Solar Particle Event – Real Time (SPE-RT) cont.



- First real time test of SPE-RT
- Positive response from SPE-RT at every pass where solar particles were measured by the MIR TEPC

Solar Particle Event – Real Time (SPE-RT) Cont.

- SPE-RT continued to over and under estimate solar particle passes
- Even though peak dose rates from SPE-RT were generally much higher than measured, the cumulative dose remained remarkably accurate due to SPE-RT calculating shorter duration for each pass
- Space shuttle shield file used due to lack of good MIR shield distribution
- SPERT over estimated the additional dose (after subtracting out GCR and SAA from measurements) to the MIR crew by about a factor of 2
- More work needs to be done to resolve missing passes, incorporating geomagnetic stormy conditions, and the magnitude and duration of passes

Electron Transport

- The primary electron transport code used by SRAG:
 - » Name - EDOSE
 - » Utilizes data tables derived from a parameterization of ShieldDose output which is based on Monte Carlo transport calculations
 - » Input
 - Electron spectrum
 - Shield distribution files
 - Shield and detector materials
 - » Output
 - Electron dose
 - Bremsstrahlung dose
 - Total dose

EVADOSE

- EVA doses are calculated preflight using master ground track trajectory information, environment models, various shield distributions, PDOSE, and EDOSE
- To estimate a crewmembers EVA dose, a proton and electron spectrum are produced during the exact time the EVA is to occur
- The trapped proton and electron doses are calculated inside and outside the vehicle using an estimate for the EMU shield distribution
- The inside dose is then subtracted from the outside dose to determine the additional exposure expected (if any)

EVADOSE cont.

- This method works fine as long as the launch is on-time, the vehicle stays exactly on it's preflight ground track, and the EVA stays exactly on time.
- Re-calculating the new EVA dose projections using the correct trajectory information was very time consuming
- EVADOSE was developed to perform these tasks automatically after an initialization file is completed (most of which is entered shortly after launch)
- EVADOSE has reduced the time to re-estimate EVA doses from about 45 minutes to 5 minutes
- EVADOSE has been crucial in helping SRAG perform ALARA by advising flight management with as much lead time as possible of radiation exposure impacts to various EVA timeline and vehicle location changes.